A specific role for Damasio's Somatic Markers in artificial decision-making: advantages and potentials for future implementations

Extended Abstract

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I. Introduction

Decision-making is a fundamental component for the creation of an autonomous artificial agent, being one of the most complex cognitive processes of our organism, constantly performed by humans and animals for survival purposes. Over the past 20-30 years several neuroscientific and psychological studies have strongly enriched our insights about the role of emotions in decision-making [1, 2, 3, 4, 5] and other cognitive processes, such as learning, memory, attention, perception, and social coordination [6, 7, 8, 9, 10]. As a consequence, starting from some of these studies, the possibility of implementing emotions in artificial decision-making systems has begun to be discussed [11, 12, 13], and in the last few years a growing number of models have been developed in order to incorporate emotion-based mechanisms in decision-making and behaviour modulation processes for different artificial agents. Such studies assigned emotions different functions and roles within the several components of decision-making process and behaviour modulation.

For instance, emotional states have been associated with predetermined action tendencies [14] or employed as additional behavioural parameters in order to provide a fast response to some emotion-eliciting stimuli coming from the environment [15]. In related works [16], some of the widely known primitive emotions (fear, boredom, anger, sadness, and hope) are represented as operators that stand for the internal states of the robot and that are activated by the agent's reactions to changes in the expectations of accomplishment of its goals. In this sense, the most important role of these emotion-inspired operators is to reprioritize agent's goals by reacting to the environment's changes. Emotions have been even implemented to improve adaptive behaviours and strategies, regulating robot's actions in respect to external eliciting stimuli [17]. Furthermore, in some other studies inspired by the concept of homeostatic regulation, the process of action selection was affected by some homeostatically controlled variables, whose decay under predetermined values activated a motivational process aimed at reinstating the correct value range of the variables by carrying out specific behaviours [18].

II. The Somatic Marker Hypoyhesis

Many different approaches and techniques followed to incorporate emotions in decision-making processes of artificial agents draw upon scientific theories and models that have identified relevant roles and functions for emotions in these internal human processes. Among them, one of the most renowned hypotheses for the role of emotions and feelings in human decision-making is the so-called somatic marker hypothesis (SMH) of Antonio Damasio [1, 19]. According to this hypothesis, when an agent faces a dilemma that presents several alternatives, for every response option considered a somatic state is generated by the body, involving sensations from the viscera, and from the skeletal as well as smooth muscles. Specifically, somatic markers (SM) are associated with scenarios that represent the various possible outcomes resulting from the available courses of actions, and they are recorded and stored in memory through association learning and experience, being evoked and felt again every time representations of scenarios and outcomes previously flagged with a somatic marker come to mind.

According to Damasio, somatic markers serve as support mechanisms for working memory and attention, and as means to rank the available decision options. In this sense, in uncertain and complex situations they help to reduce the available courses of actions by marking response options with a positive or negative "emotional" signal, in a conscious or even unconscious fashion. Thus, only those options that are marked as promising are then taken into consideration for a subsequent cost/benefit rational analysis [1].

III. The Somatic Marker Hypothesis in Artificial Decision-making Models and Architectures

Considering the complexity of Damasio's hypothesis, it is certainly interesting to explore how the mechanism of somatic markers could be engineered to be incorporated into artificial agents and robots that must face decision-making scenarios. Quite surprisingly, among the literature regarding the implementation of emotion-based mechanisms in artificial decision-making processes there are only few proposals that have specifically explored the possibility of incorporating somatic marker mechanisms in decision-making architectures [20-26].

Some of these proposals mainly consist of computational models or decision-making algorithms that conceive somatic markers as positively or negatively valenced states assigned to each response option and that act as a filtering mechanism, affecting the elimination or selection of the available options and creating an actions' subset for a following stage of rational analysis or preference expression [23, 24]. Besides, some of these models involve mechanisms aimed at constantly updating and adapting somatic markers' values, according to the evaluation of the positive or negative outcomes that follow an action [21, 24]. This process has been also carried out by designing an emotional memory that replicates the associative learning mechanism between artificial emotions and a certain stimulus, so that a second interaction with an already marked stimulus will reproduce a particular emotional state stored in memory, affecting the action selection process [22].

IV. A specific Role for Damasio's Somatic Markers in Artificial Decision-making

Considering the examples available in literature and the few experimental results, we reckon that it is worth further exploring the possibility that somatic markers could profitably be engaged in two different phases of the five identified by Linquist and Bartol to describe human as well as artificial decision-making process [27]. Particularly, we believe that SM-based mechanisms should be implemented in models and architectures to act in the third and fourth phases of the decision-making process as described by these authors, namely the stage of deliberation and the ranking phase.

The deliberation phase coincides with two different functions potentially played by somatic markers. The first one is the identification of implications and "factors" connected with the options at hand that are judged relevant and thus taken into account for the decision. In this sense, somatic markers act as a sort of assistance mechanism that highlights the most relevant criteria to be factored and evaluated in the decision [1, 28]. The second function carried out by the markers is putting a limit to the amount of time and energy we spend for that specific deliberation.

In the ranking phase, the somatic markers work as weights against or in favour of a certain option. More specifically, during this phase the evaluation of a particular option can trigger a somatic marker, which assigns a positive or negative value to the option itself. At this stage, according to Damasio [1], somatic markers even work as criteria to build a general ranking of the options at hand, expressing our preferences acquired through experience and stored in memory. Playing these functions, the markers serve to further reduce the number of options that the agent will consider for making the final decision.

V. Consequences and Potentialities for Implementation purposes

We reckon that this hypothesis about the exact roles and functions played by somatic markers in human decision-making could pave the way for an implementation path that is worth exploring, possibly leading to several advantages related to the potential improvement of some aspects of the artificial decision-making process and even interesting consequences with respect to the quality of the interaction between the robot and other entities or agents present in its environment.

Firstly, considering the contribution of somatic markers in the deliberation and in the ranking phase of the decision-making process, we believe that it is possible to improve accuracy as well as speed of artificial decision-making. About the former, it is sufficient to consider some of the experimental results derived from the reproduction of the so-called Iowa Gambling Task [21, 23, 25], designed by Damasio and Antoine Bechara to verify the role of somatic markers in decisions characterized by a great amount of uncertainty and unpredictability [1, 29]. These results show an increased effectiveness in performing the task by the architectures and models provided with a SM-based mechanism, that sometimes obtained similar or slightly better results than the healthy subjects who underwent to the Bechara's experiment [21], and in some cases overcame by a considerable margin the performance of architectures devoid of a SM-mechanism [25]. Furthermore, it is evident that the results collected from the tests show that the emotional preselection carried out by the somatic markers possesses a fundamental role even in preventing the agent from selecting through the rational analysis an alternative which could have been eliminated by the somatic marker's filtering mechanism [20].

Regarding the possibility of speed improvement, it is relevant to notice that nearly all the recent architectural implementations and computational models have verified that providing somatic markers with the option filtering function allows to deliver a subset of the available action options for a given decision to a subsequent rational processing phase, thus saving computing times and easily encountering real-time expectations [20, 21].

The second relevant aspect connected to the implementation of a SM-mechanism in artificial decision-making which is worth considering is the possibility offered to the robot or the artificial system to develop a personal and diversified view of the world around and of the events, entities, and subjects with which it comes into contact. This can be obtained through a reinforcement learning process [22, 25] and an emotional memory which records the association of a somatic state with a particular object or stimulus that occurs to the system, reinforcing or discouraging the selection of a decision option or of a particular behaviour with somatic rewards or punishments. This is a potentiality that has already been highlighted by some recent somatic marker applications and experimental results [25], and might represent an interesting future path of experimentation, particularly for social robotics and for many other application scenarios where the artificial agent would be required to cope with frequent human interaction and with an ever-changing environment.

Eventually, we believe that the SMH conceived in these terms can represent a really profitable and fertile approach for the design of future architectures and computational models aiming at realizing emotion-based decision-making, for all the reasons explained above. However, we reckon that deepening this exciting research path will certainly require to overcome the current testing procedures and to start applying SM-based architectures to real robots in more complex and interactive environments, in order to verify their real capabilities and potentialities.

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